DISTRIBUTED AIR/GROUND TRAFFIC MANAGEMENT SIMULATION: RESULTS, PROGRESS AND PLANS

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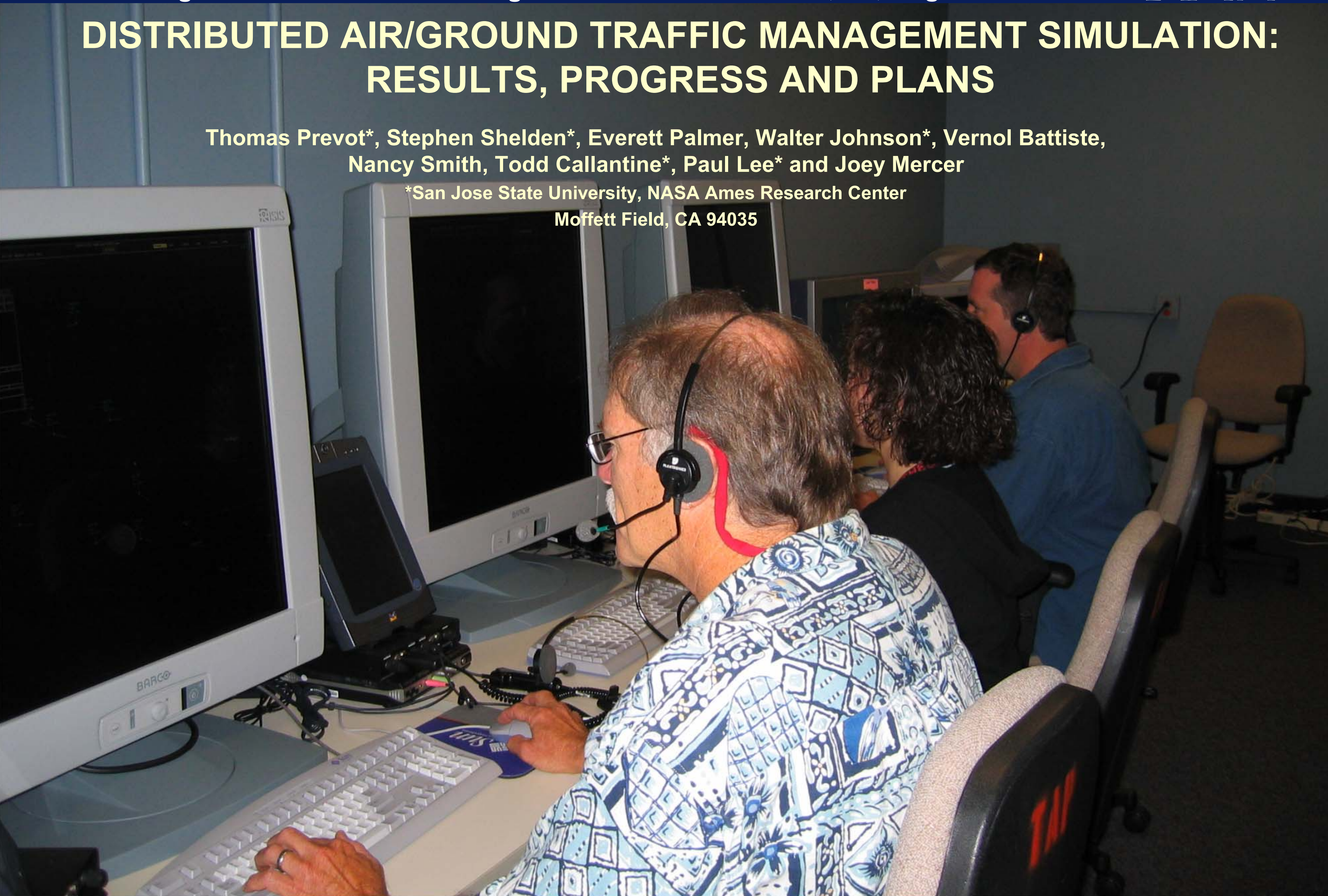


Contents

Introduction

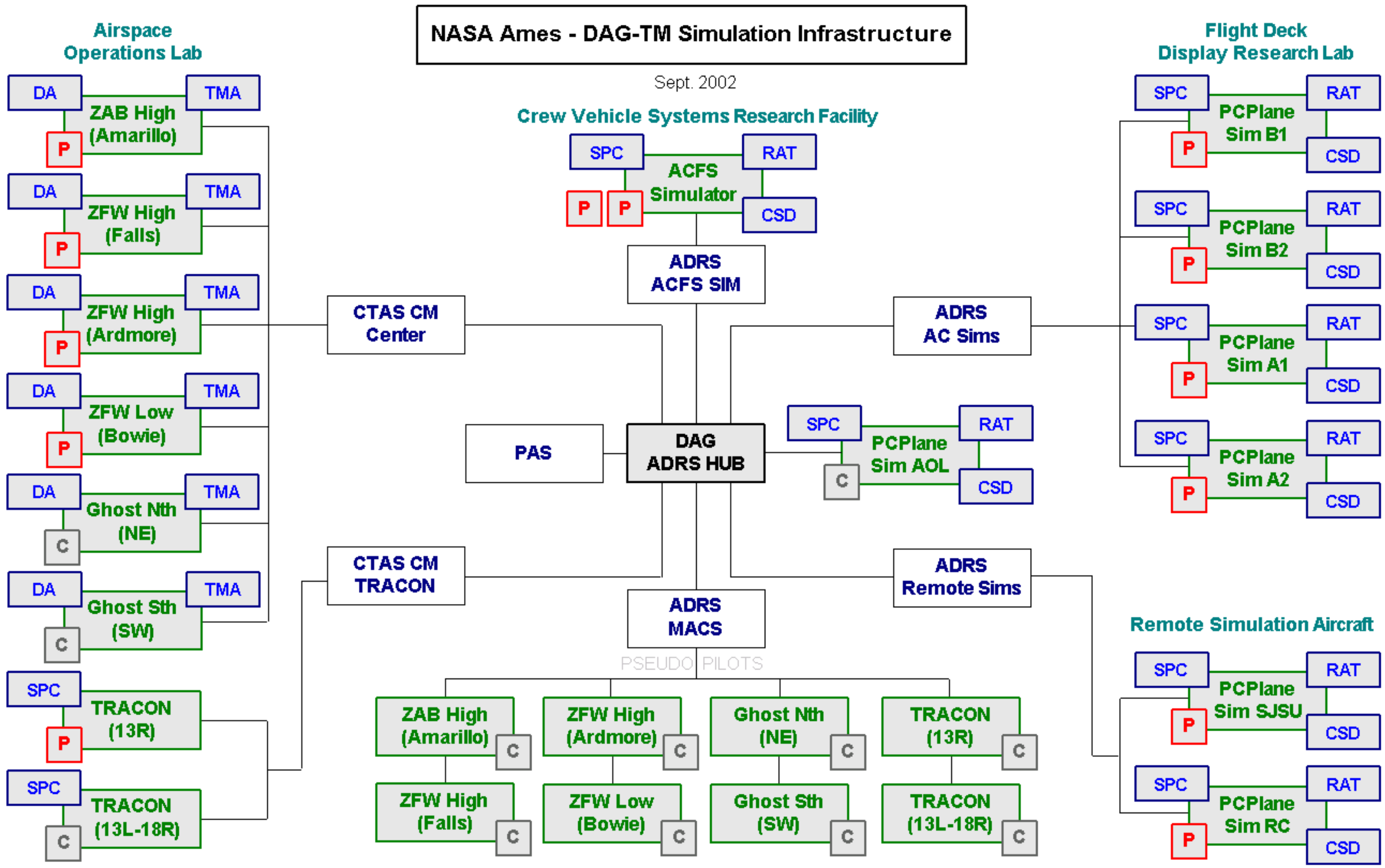
- Air traffic management research of future concepts needs to address all players including flight crews, air traffic controllers/ managers and airline dispatchers adequately

- Among the ways of addressing the problem are
  - Include many participants (pilots, controllers, dispatchers) in a given air traffic simulation to work all sides of the problem adequately
  - Include automated agents for side aspects and human participants only for the focus area of the research

- A initial multi-fidelity simulation environment for air ground integraton research has been created over the past years at NASA-Ames Research Center*

*Prevôt, T., E. Palmer, N. Smith, and T. Callantine, 2002, *A multi-fidelity simulation environment for human-in-the-loop studies of distributed air ground traffic management*, AIAA MST 2002, AIAA-2002-4679, Reston, VA.

2002 Simulation Environment



ACFS Advanced Concepts Flight Simulator
ADRS Aeronautical Datalink and Radar Simulator
CM Communications Manager
CSD Cockpit Situation Display
CTAS Center TRACON Automation System

DA Descent Advisor (CTAS)
FAST Final Approach Spacing Tool (CTAS)
MACS Multi Aircraft Control System
PAS Pseudo Aircraft System (traffic generator)
TMA Traffic Management Advisor (CTAS)

RAT Route Assessment Tool (CSD)
SPC Spacing Capability (CSD)
P Participant
C Cohort Position

ZFW High (Ardmore) Operator Station
ADRS Processor
SPC Decision Support Tool

2002 Simulation environment

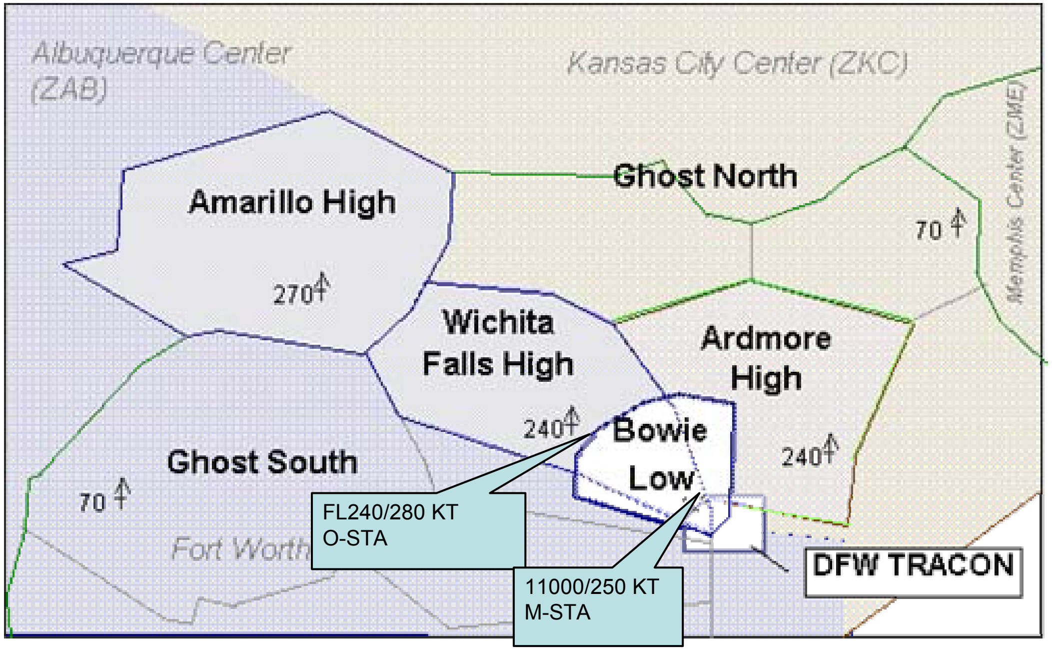
Advanced Concepts Flight Simulator
(NASA ARC)

Air traffic control stations

Multi Aircraft
Displays and
Controls
(NASA ARC)

September 2002 Simulation

- Current day peak arrival traffic in northwestern ZFW area
- ~90 aircraft (half arrivals, half overflights and departures)
- Metering to 7 nautical miles in trail -> delay 2 to 5 minutes
- 5 controller participants (1 high altitude en route, 2 high altitude arrivals, 1 low altitude arival, 1 TRACON)
- 2 pilot participants in full mission simulator
- 6 pilot participants controlling desktop simulators
- 3 confederate controllers
- 8 confederate pilots handling Multi Aircraft Control Stations (MACS)
- Observers on each participant position
- Comprehensive data collection



Simulation: Conditions

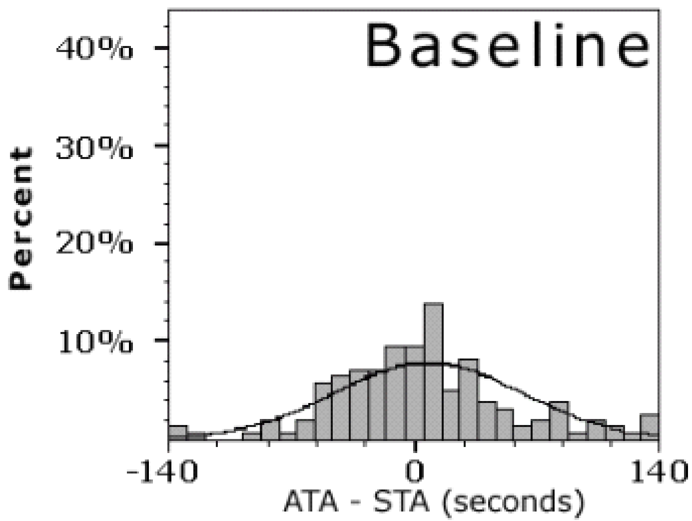
Control Condition
Enhanced current day metering

- Data link
  - ADS-B for state and trajectories
- Controllers:
  CTAS-based Decision Support Tools
  - Meter list
  - Delay information in data tag
- Flight Crews:
  - Cockpit Display of Traffic Information (CDTI)
- Procedures
  - Current day operations

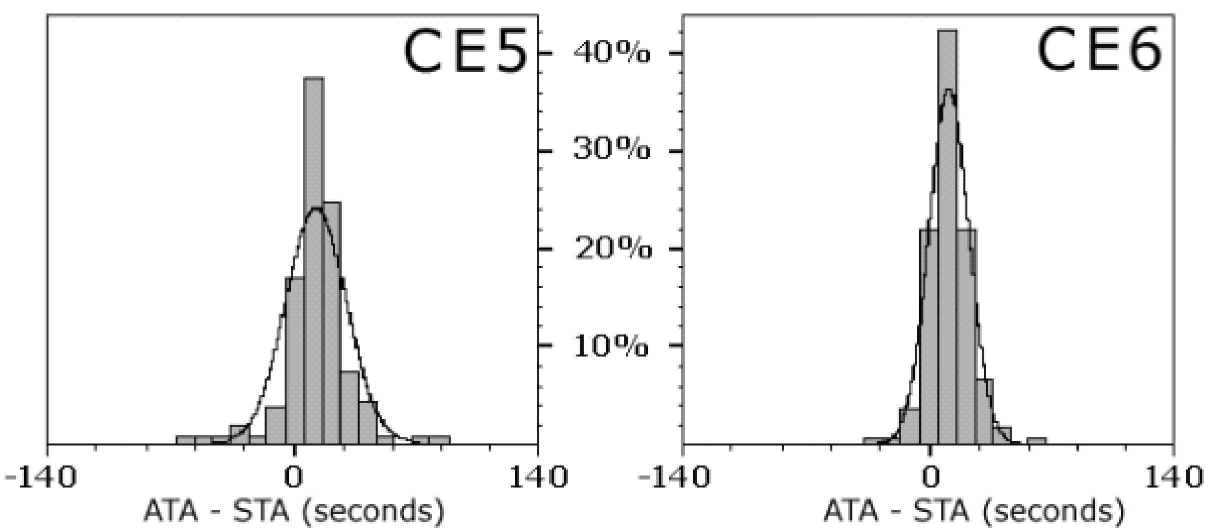
DAG-TM Experimental Conditions
- CE6: Trajectory negotiation
- CE5: Free maneuvering

- Data link
  - ADS-B for state and trajectories
  - CPDLC integrated with DSTs for trajectory data exchange
- Controllers:
  CTAS-based Decision Support Tools
  - Timeline display
  - Cruise/descent speed advisory
  - Route modification trial planning
  - Conflict probe
- Flight Crews:
  - CDTI
  - Route Assessment Tool (RAT)
  - Conflict probe
  - Experimental Required Time of Arrival (RTA) function
- Procedures
  - Precision Descent procedure

Results: Arrival Accuracy for all aircraft



Arrival accuracy varied significantly more under the baseline condition (SD = 53.9) than either CE 6 (SD = 11.4) or CE 5 (SD = 17.2), suggesting that more aircraft were delivered on time using DAG-TM arrival metering than in current day operation



"Free maneuvering"

"Trajectory negotiation"

Results: Arrival Accuracy for Participant Aircraft

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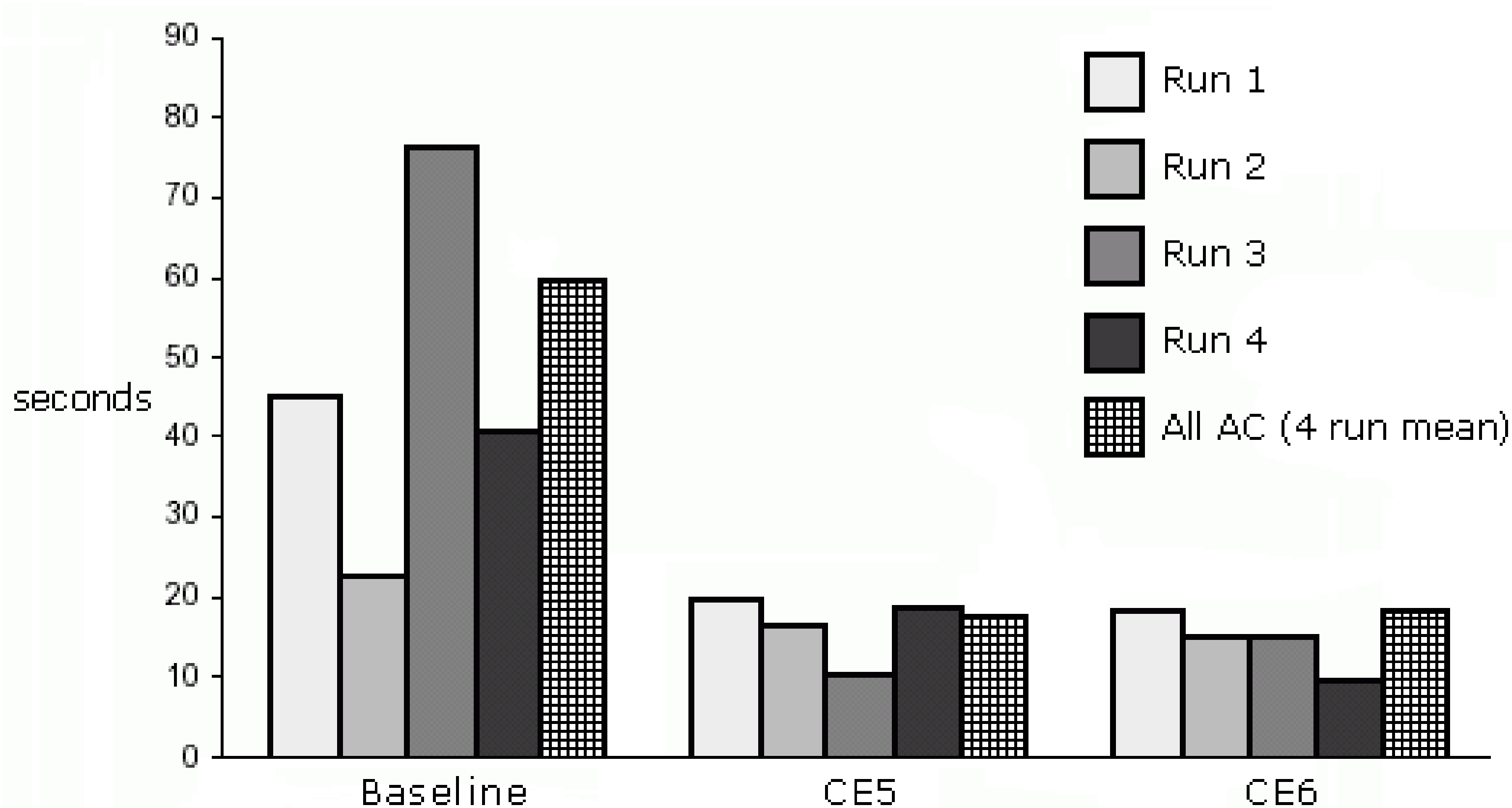
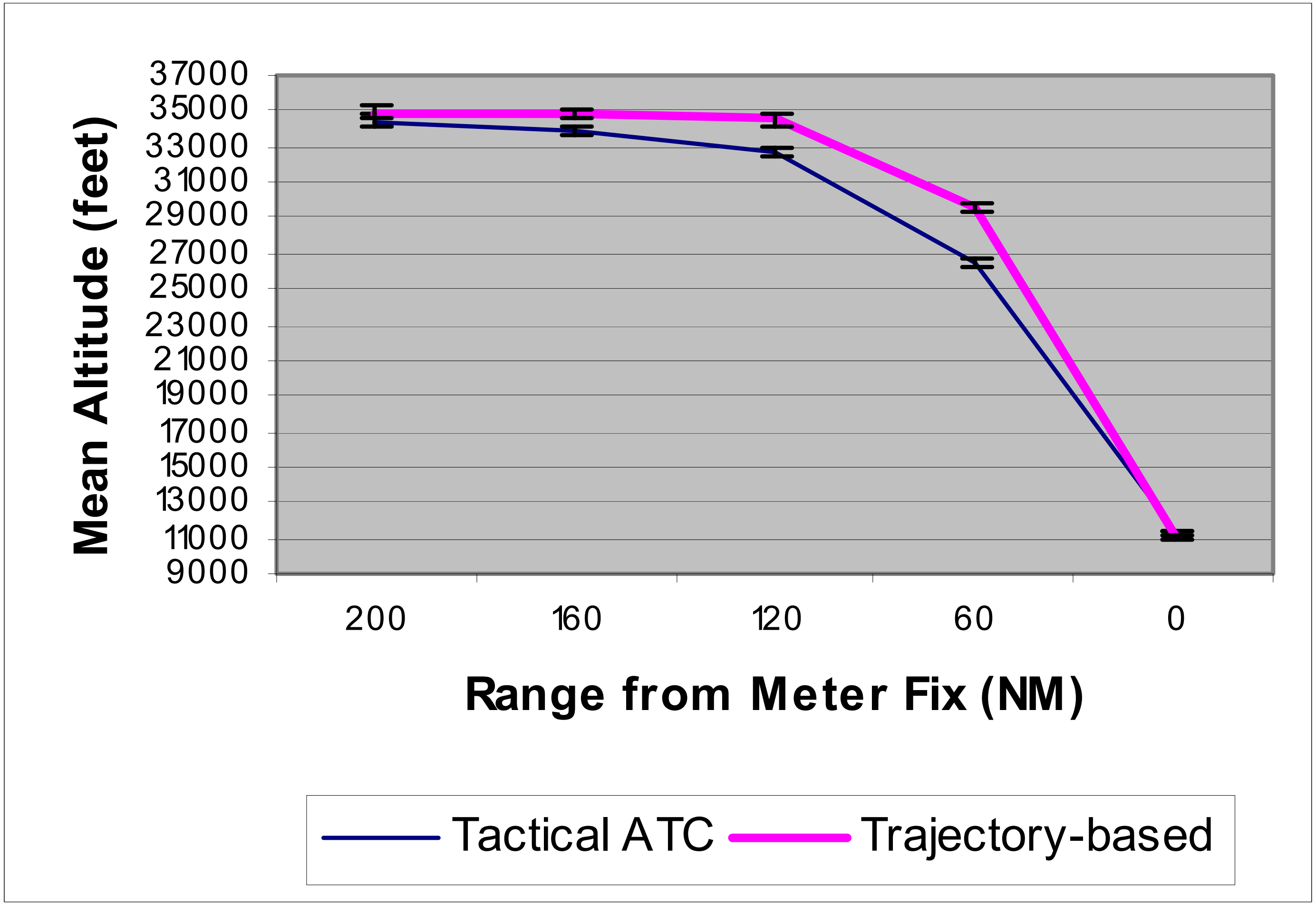
Absolute meter fix crossing deviation: participant aircraft (versus the all-aircraft average across 4 runs)



“Free maneuvering” “Trajectory negotiation”

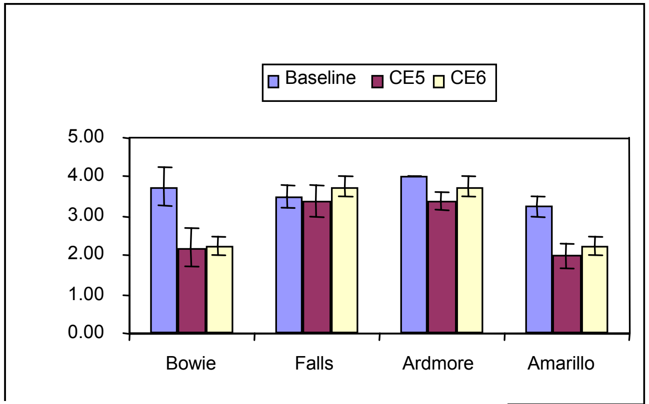
Results: Mean Altitude of Arriving Aircraft

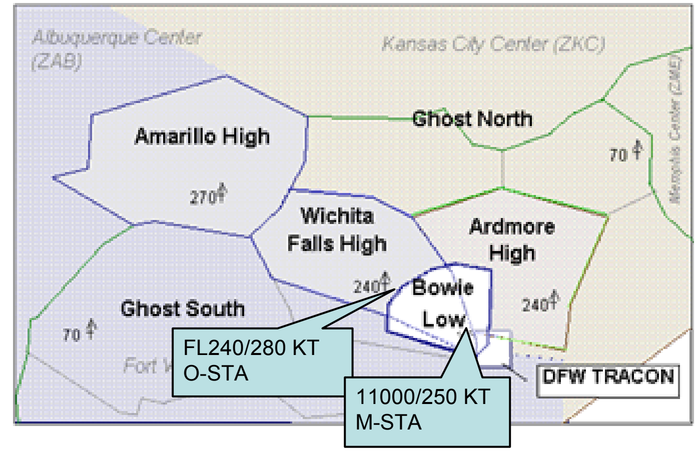


More aircraft could stay longer at a higher altitude in the experimental conditions

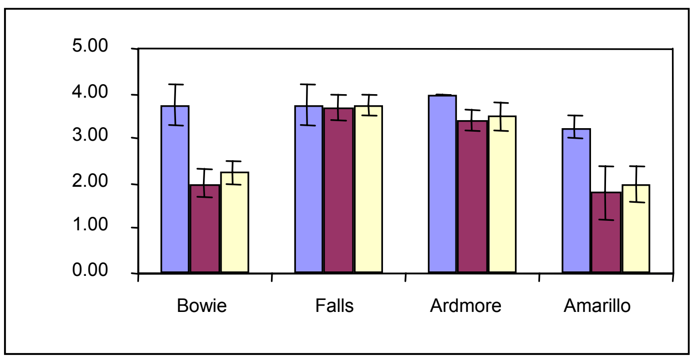
Results: Controller Workload

Mental Demand

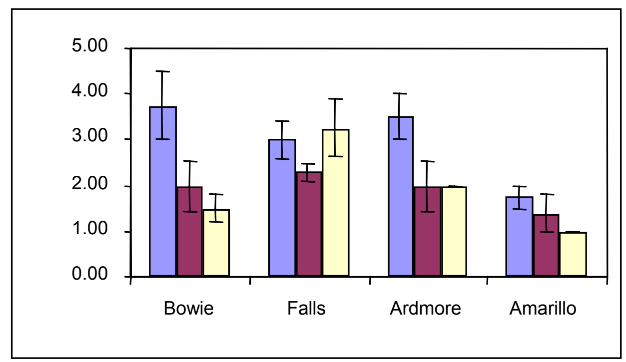




Effort

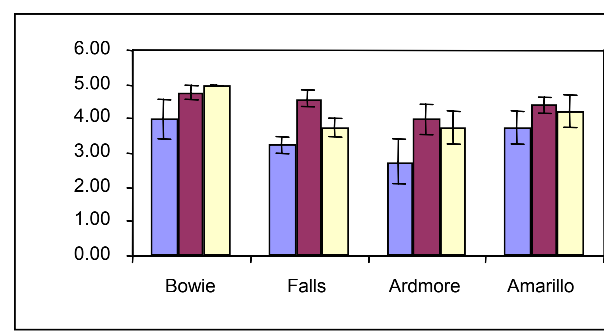


Frustration



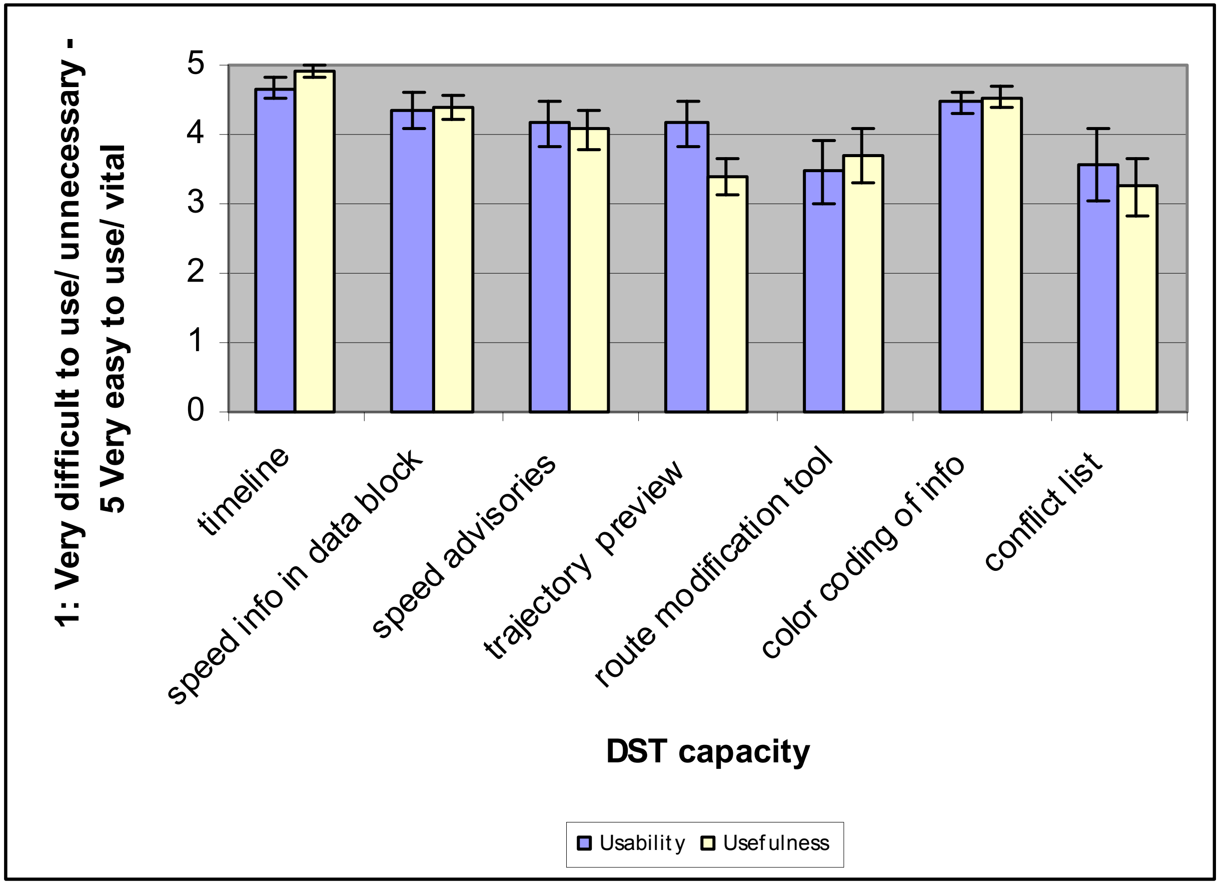
The low altitude controller (BOWIE) reported the greatest benefit from the trajectory-based experimental operations

Performance



Results: Usability and Usefulness of Different Tools

Mean and standard error of usability and usefulness



Observations and post-run questionnaires from 13 controllers who had each used variations of the same toolset for several days (usually 4 days training and 4 days experimental runs) to control arrival traffic in a trajectory-oriented manner. The data was gathered in 3 simulation studies in 2002.

Desired improvements to simulation environment

- Generic controller interfaces
  - Unfamiliarity with generic CTAS-based controller interfaces increases training time and/or can blur the data due to errors unrelated to the tested operational concepts
- Number of pro-active pilots
  - Many pilots are expected to play an active role in the trajectory negotiation or free maneuvering tasks
- Voice communication system
  - The analog voice communication system provides only for 14 participants. Many more are required for DAG-TM research
- Real-time weather feed
  - Testing the feasibility of DAG-TM concepts requires simulating operations under all weather conditions. Therefore, a weather server is added to the simulation environment

2003/2004 Simulation Architecture

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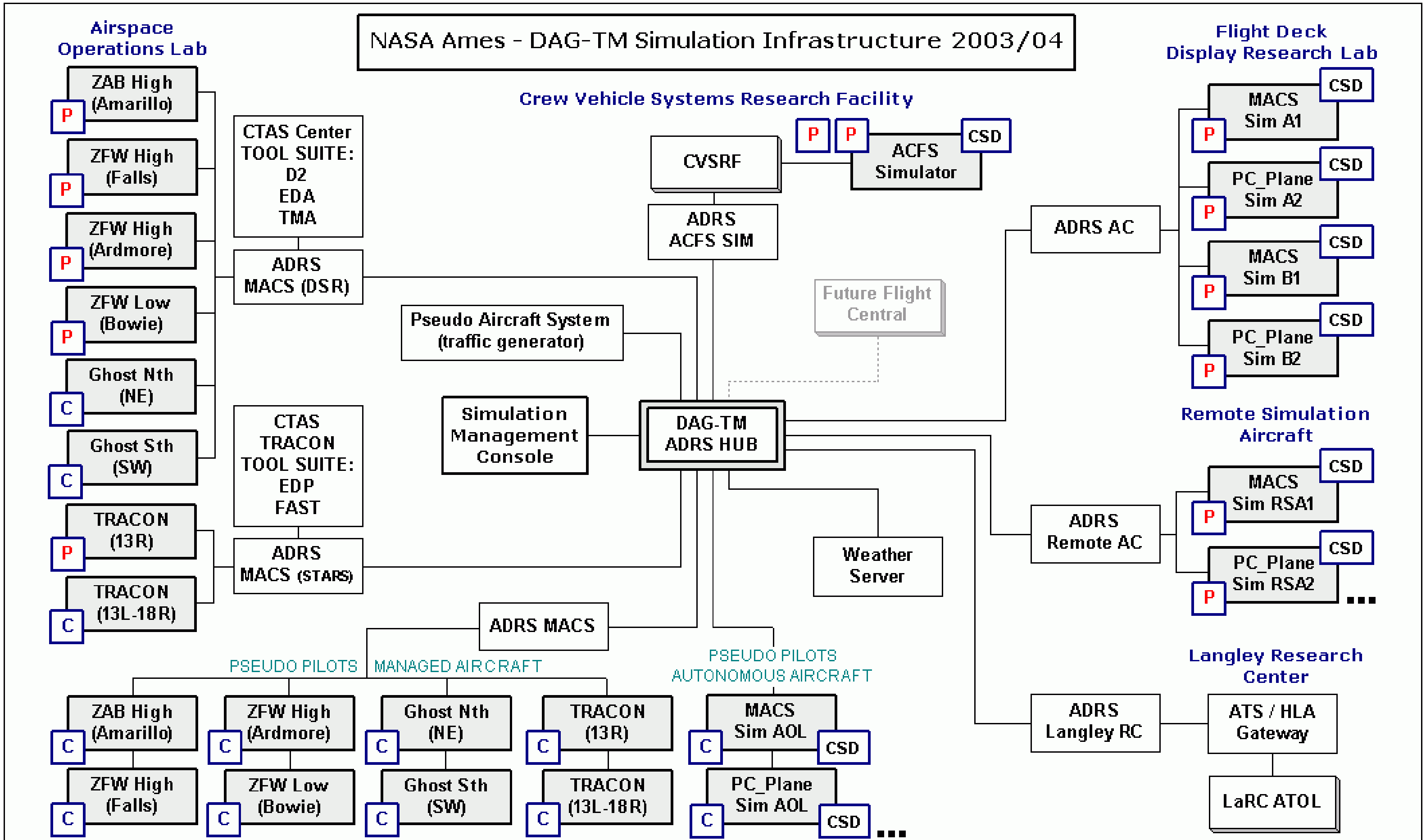


ACFS Advanced Concepts Flight Simulator
ADRS Aeronautical Datalink and Radar Simulator
ATOS Air Traffic Operations Simulator
ATS Air Traffic Simulator
HLA High Level Architecture
MACS Multi Aircraft Control System
STARS Standard Terminal Arrival Routing

CSD Cockpit Situation Display
CTAS Center TRACON Automation System (Tools)
D2 Direct To
EDA Enroute Descent Advisor
EDP Expedited Descent Path
FAST Final Approach Spacing Tool
TMA Traffic Management Advisor

MACS Operator Station (... more units)
ADRS Processor
Lab External Lab
P Participant
C Cohort Position

Airspace Operations Laboratory at Ames

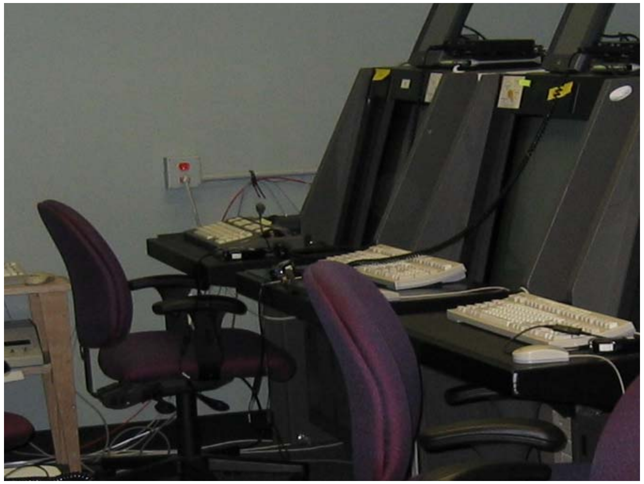
Experiment Control

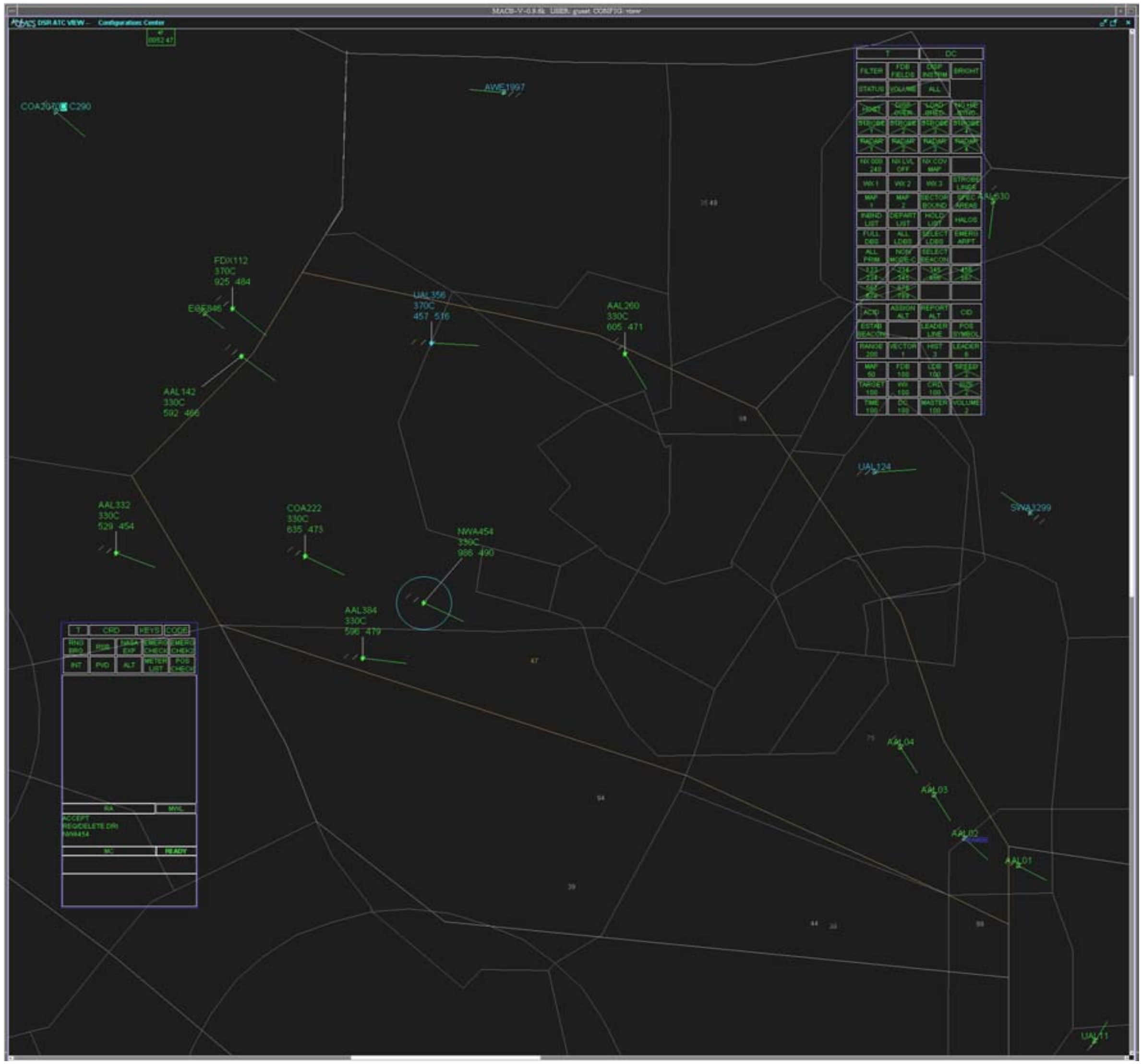
Pseudo pilot stations

ATC Center Operations

ATC TRACON Operations

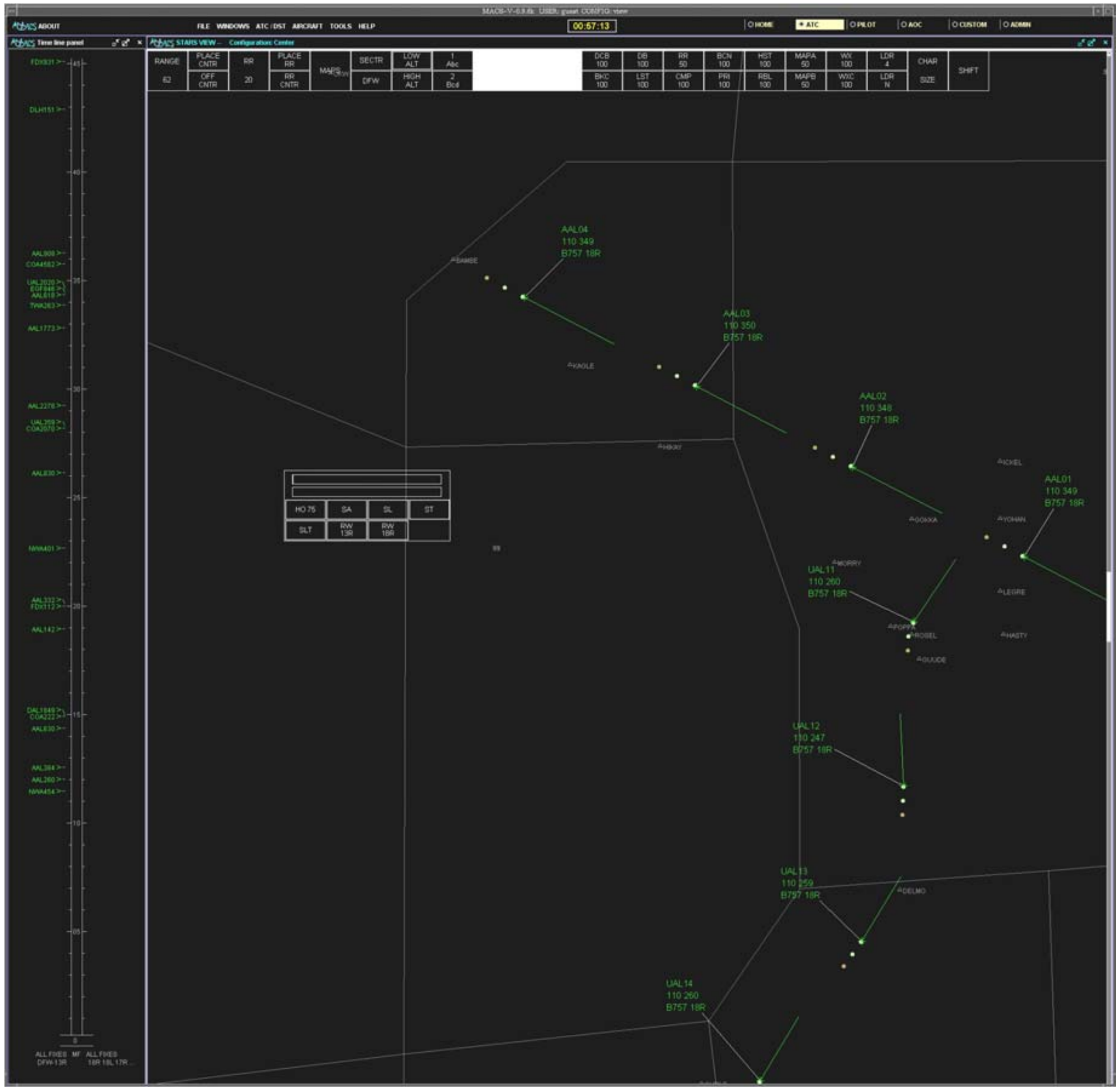
Controller Interfaces: MACS DSR Center displays





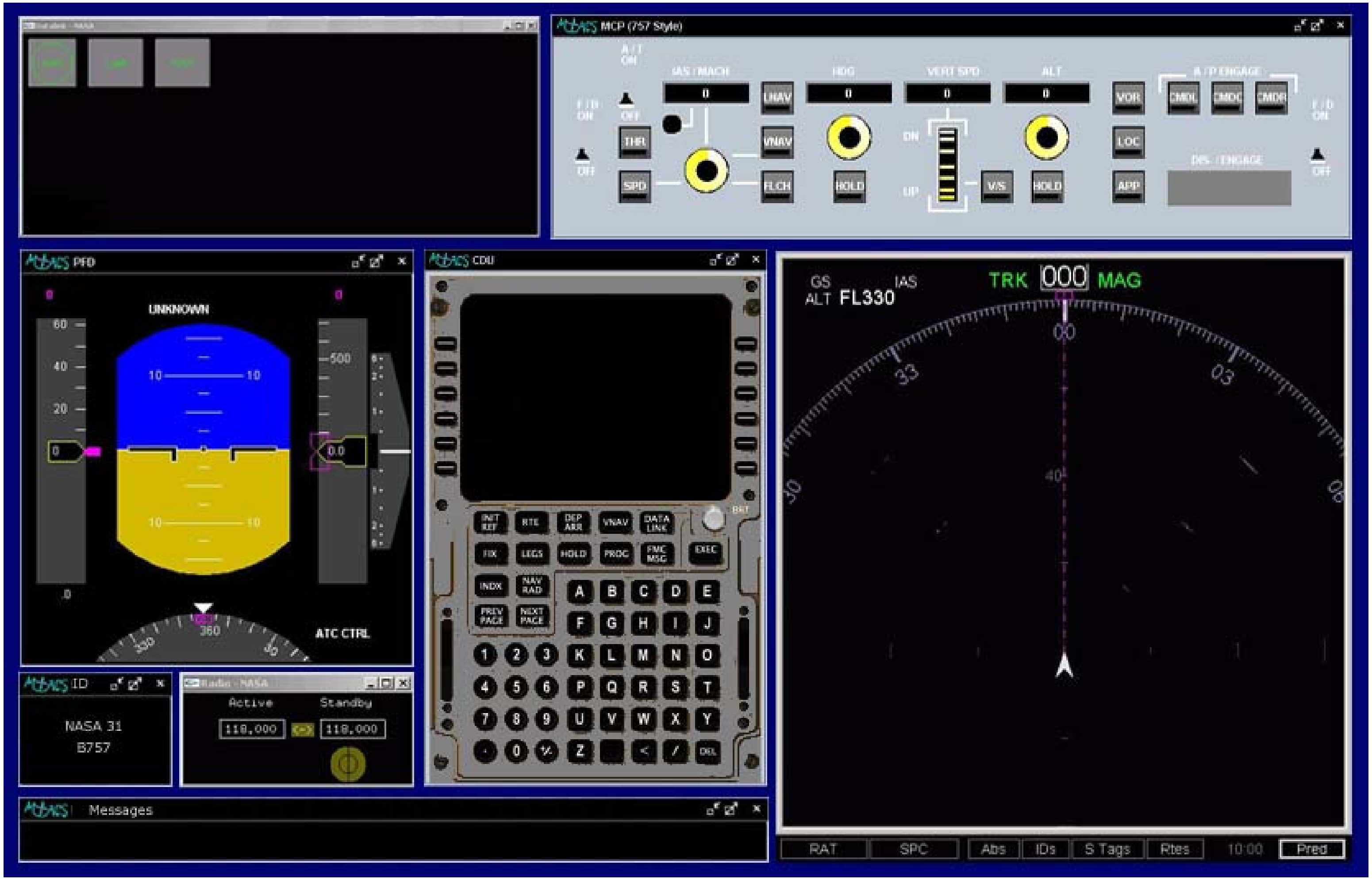
Mock-ups of Center and TRACON controller interfaces have been implemented as part of the Multi Aircraft Control System (MACS). These displays combined with the actual entry devices (keyboard, trackball) are intended to provide a familiar Look & Feel (L&F) to controllers. Thus, controllers need to be trained only on (minor) differences and new DSTs; and some of the unknowns from the experimental data are removed.

Controller Interfaces: MACS STARS TRACON displays



A standard terminal automation replacement system (STARS) replica has been emulated in MACS. Data entries can be done via a STARS keyboard and trackball as well as standard computer keyboards and trackballs.

MACS/CDTI combination for single aircraft pilots



A melding of MACS and CDTI elements will form the new single aircraft participant pilot desktop simulator station.

MACS/CDTI combination for multi aircraft pilots

Example MACS station equipped with CDTI and agent support controlling several (here 6) aircraft

Voice communication system over Internet Protocol (VoIP)

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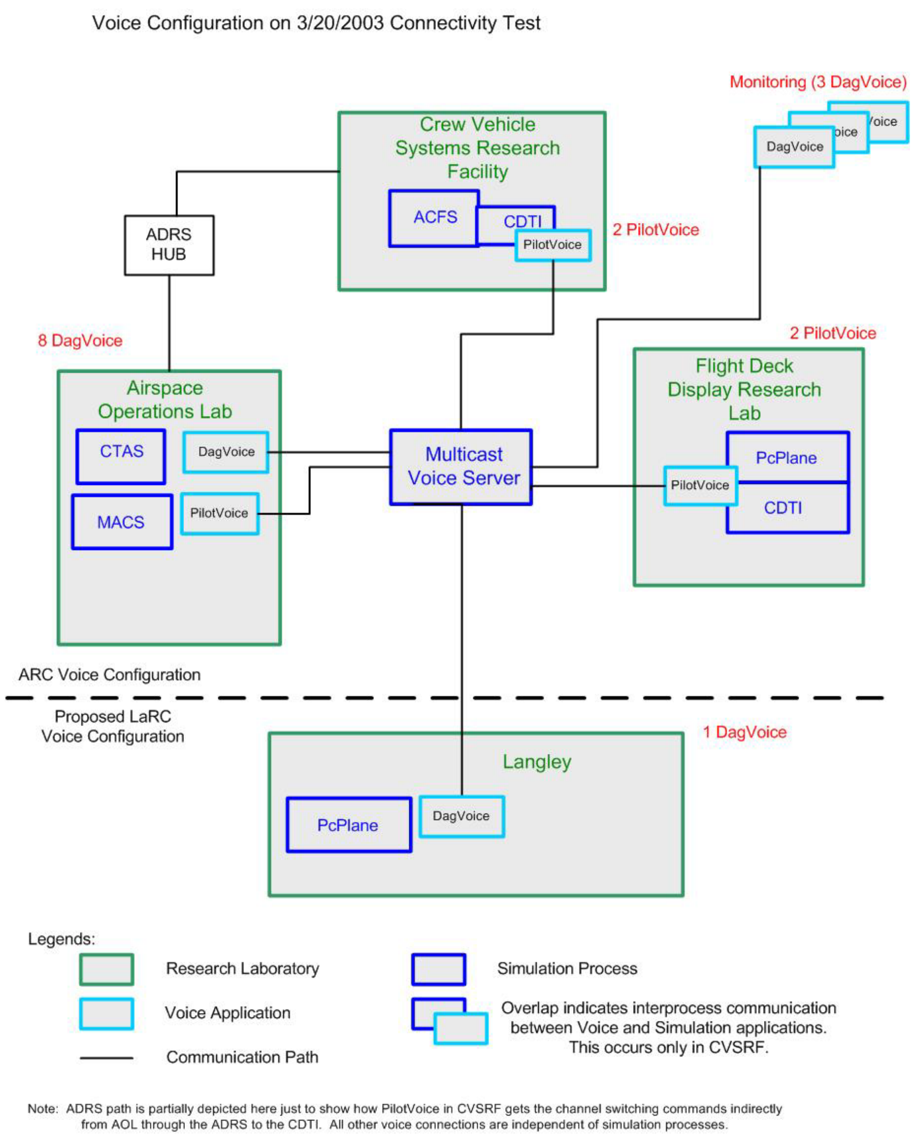
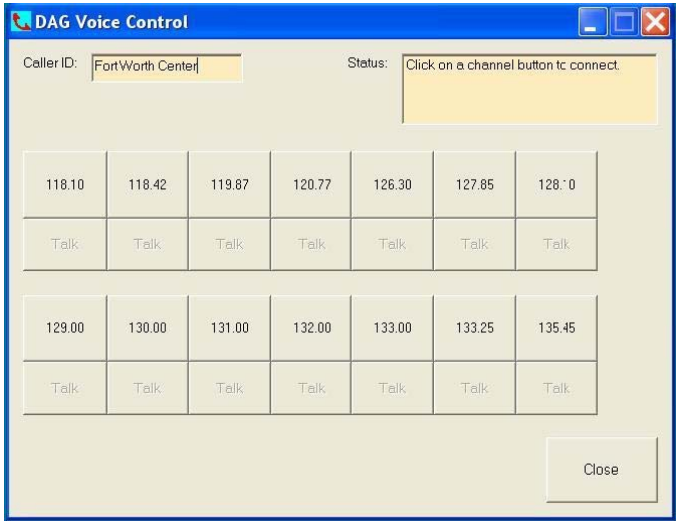
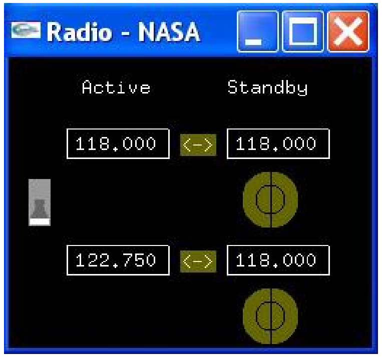
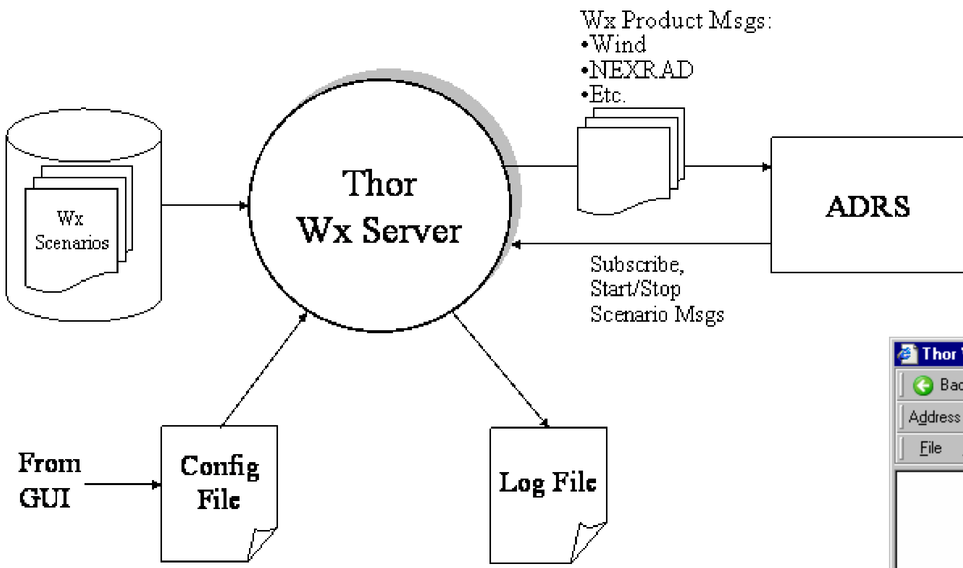




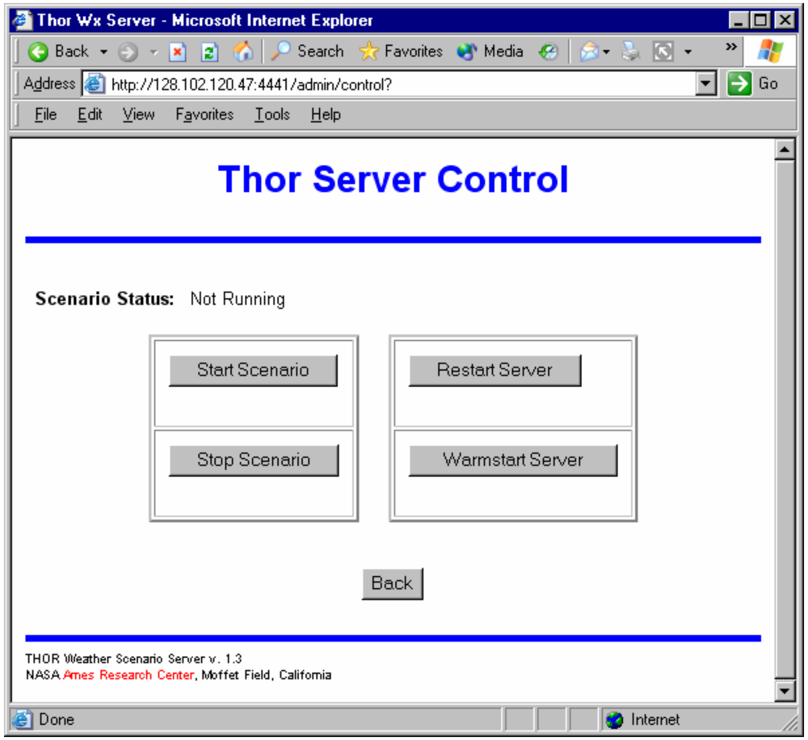
The voice system supports 14 voice channels. Up to 50 speakers overall can be accommodated across all channels on one voice server.



Real-time weather feed



The Thor Weather Scenario Server (named after Thor, the Norse god of thunder) is a data server designed to provide weather data to flight decks–with and without out-the-window- visual scenes, ground ATC, and other application requiring access to time-varying, real-world weather.



Model-based agent support

- Agent-based simulations already prevalent within the ATC/ATM research community

- DAG-TM simulation research can benefit from agents operating with various levels of autonomy for a variety of purposes
  - perform ATC and piloting tasks
  - detect operator errors
  - generate performance metrics
  - perform basic simulation-support tasks

- Agents can function as air traffic controllers and pilots standing in for confederates in human-in-the-loop studies
  - reduce costs
  - improve consistency

- Detailed discussion in Callantine et al. (2003) AIAA-MST03

Connection to ATOL at NASA Langley Research Center

- Connectivity between both laboratories is initially established
- Aircraft simulated at Ames and Langley can be combined in one scenario
- Large scale Distributed Air Ground Traffic Management (DAG-TM) simulation of “en route free maneuvering” and “TRACON merging and spacing” planned for spring 2004

Concluding Remarks

- Realistic human-in-the-loop simulations of DAG/TM concepts require participation of numerous pilots, controllers, airline dispatchers, researchers and the operational community alike in order to gain a solid understanding of interactions in the very complex distributed air traffic environment

- A simulation infrastructure was created at NASA Ames Research Center that covers many requirements for appropriate fidelity levels

- The initial environment has been successfully used in research studies and demonstrations. Shortcomings have been determined and the identified upgrades are currently phased into the simulation architecture

- The development work to integrate the Ames-based simulation with NASA Langley's Air Traffic Operations Laboratory (ATOL) is well underway

Acknowledgements

NASA Ames Research Center:
- Sandy Lozito and her research team
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